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Application of photoconductivity measurements to photodynamic processes investigation in $LiYF_4:Ce^{3+}$ and $LiLuF_4:Ce^{3+}$ crystals

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ABSTRACT

Photoconductivity measurements are applied to the studies of photodynamic processes in $LiYF_4:Ce^{3+}$ and $LiLuF_4:Ce^{3+}$ crystals undergoing ultraviolet irradiation. Photoconductivity spectra were registered by means of microwave technique under irradiation at 220–320 nm at the room temperature. Photoconductivity signal appeared at ~300 nm and monotonically increased with the shortening of wavelength. Pumping energy dependencies of photoconductivity within 225–305 nm spectral range were registered and revealed the change of the dependence degree from quadratic at longer wavelengths through linear to saturation-like at shorter ones. Numerical simulation based on four-level model of photodynamic processes was performed. Values and spectral distributions of probabilities of different types of photodynamic processes for 225–295 nm were estimated. Ce^{3+} ions excited-state photoionization cross-section spectra in both investigated materials revealed a band with a peak around 270 nm most probably corresponding to 5d–6s transition of Ce^{3+}. Recombination cross-section in $Ce:LiLuF_4$ appeared to be two orders of magnitude higher than in $Ce:LiYF_4$. A complete energy level diagram of "Ce^{3+} ion–$LiYF_4$ crystal" system has been proposed.

1. Introduction

The advancement of science and industry causes demand for compact, inexpensive and reliable UV lasers preferably with a wide tuning range. However, in the majority of solid-state active media UV radiation induces so-called photodynamic processes (PDP) [1]. Such processes as excited-state absorption followed by ionization of activator ions (excited-state photoionization or ESP), color centers formation and so on are usually considered harmful and lead to the degradation of active media performance.

Photodynamic processes involve not only intracenter transitions of active ions but transitions to the energy levels of crystal lattice as well [2]. Therefore, in order to create an adequate model of these processes it is essential to know how energy states of the both subsystems are situated relative to each other. It is rather difficult to provide such a complete energy level diagram solely by means of traditional spectroscopy because of the overlapping of spectra corresponding to the activator ions, color centers and crystal lattice itself, on the one hand, and the certain experimental difficulties arising in the short-wave range of the UV spectral region (VUV), on the other. And this is where photoconductivity measurements could be of use. The fact is that photoconductivity technique allows direct studies of PDP. It is based on registration of the free charge carriers' formation in the conduction and valence bands of the insulating material undergoing UV irradiation [3].

This investigation aims to apply photoconductivity measurements to the investigation of PDP. As a result numerical and spectral characteristics of PDP are determined and applied to construct a complete energy level diagram of the joint "activator ion–crystal lattice" system.

2. Investigated materials

Ce^{3+}-activated $LiYF_4$ (LYF) and $LiLuF_4$ (LLF) crystals are well-known active media for UV lasers since the end of the last century [4,5]. However, under UV radiation both materials are subjected to a strong coloration effect deteriorating their performances, which makes these crystals excellent model objects for the investigation.

Samples used here have been grown and prepared in the Laboratory of crystal growth of Kazan Federal University by means of Bridgman technique in graphite crucibles. As a result pure as well as Ce^{3+}-activated (1 at.% in the melt) LYF and LLF crystals were grown and 2 mm thick disk-shaped samples with two polished surfaces were prepared. Optical axes of the samples were situated in the planes of the polished surfaces.

3. Experimental technique

Microwave technique of photoconductivity registration was adopted from EPR-spectroscopy and is thoroughly described in

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